

Grazia Vannucci*, Michele Piazza*, Patrizia Fravega*
&
Claudia Consigliere**

New data and comparisons on red calcareous algae
and larger foraminifera assemblages from
Gàssino Formation
(Eocene; Monferrato and Torino Hill, NW Italy)

Abstract - The reworked bioclastic limestone body of San Martino (Gàssino Fm.) are here described with special attention to the red calcareous algae assemblages. The shallow benthic foraminifera assemblage indicates a time interval spanning from the upper part of late Bartonian to the end of early Priabonian. Both algae and larger foraminifera assemblages are discussed in terms of their paleoecological meaning, in order to define the source of these transported materials, which may be confidently assigned to the middle/upper part of the Circalittoral Zone. The recovered taxa are discussed with regard to their paleogeographic meaning. Finally, the algae assemblage is compared to that recovered in the exposure of Gàssino Formation of Cascina Spinosa Alta (Monferrato complex).

Key words: Red calcareous algae, Eocene, paleoecology, paleobiogeography, Torino Hill and Monferrato Complex.

Riassunto - Nuovi dati e confronti sulle alghe calcaree rosse della Formazione di Gàssino (Eocene, Monferrato e Collina di Torino, Italia Nord-occidentale).

In questo lavoro viene descritto l'affioramento di calcari bioclastici risedimentati di San Martino (Formazione di Gàssino), con particolare attenzione per le associazioni ad alghe rosse calcaree. I foraminiferi bentonici indicano un'età compresa fra la parte terminale del Bartoniano superiore e la fine del Priaboniano inferiore. Le associazioni algali ed a macroforaminiferi sono state studiate in chiave paleoecologica al fine di identificare le caratteristiche delle zone di provenienza dei materiali bioclastici risedimentati. Le indicazioni ottenute suggeriscono condizioni di fondali del Circalitorale medio/superiore di clima tropicale/subtropicale, interessati da moderato-bassa energia idrodinamica, ubicati ad una profondità probabilmente compresa fra 60 m e 80 m. I taxa identificati sono stati considerati per il loro significato paleobiogeografico che, nel complesso, risulta marcatamente tetideo-paleomediterraneo. Infine, l'associazione algale viene confrontata con quella presente nei corpi calcarei bioclastici di Cascina Spinosa Alta (Monferrato).

Parole chiave: Alghe rosse calcaree, Eocene, paleoecologia, paleobiogeografia, Collina di Torino e Monferrato.

Introduction

The aim of this study is to compare and discuss the fossil algae assemblages recov-

*Dipartimento per lo Studio del Territorio e delle sue Risorse, Università degli Studi di Genova, Corso Europa 26, 16132 Genova, Italy, e-mail: vannucci@dipteris.unige.it

**Via Raffaele Ricca 18/26, 16139 Genova, Italy.

ered in resedimented bioclastic levels occurring in the Eocene Gàsino Formation (Torino Hill and Monferrato Complex). The here considered fossil material is from the sites of Cascina Spinosa Alta (Monferrato complex, Consigliere *et al.*, 2004) and San Martino (Torino Hill, new data reported in this paper). The red calcareous algae and larger foraminifera assemblages recovered in the Eocene Gàsino Formation cropping out in the neighbourhood of the locality San Martino, Torino Hill (Fig. 1) are described and discussed for their biostratigraphic, paleoecologic and paleobiogeographic meaning.

The Gàsino Formation

The Gàsino Formation is a lithostratigraphic unit involved in the distinct folded

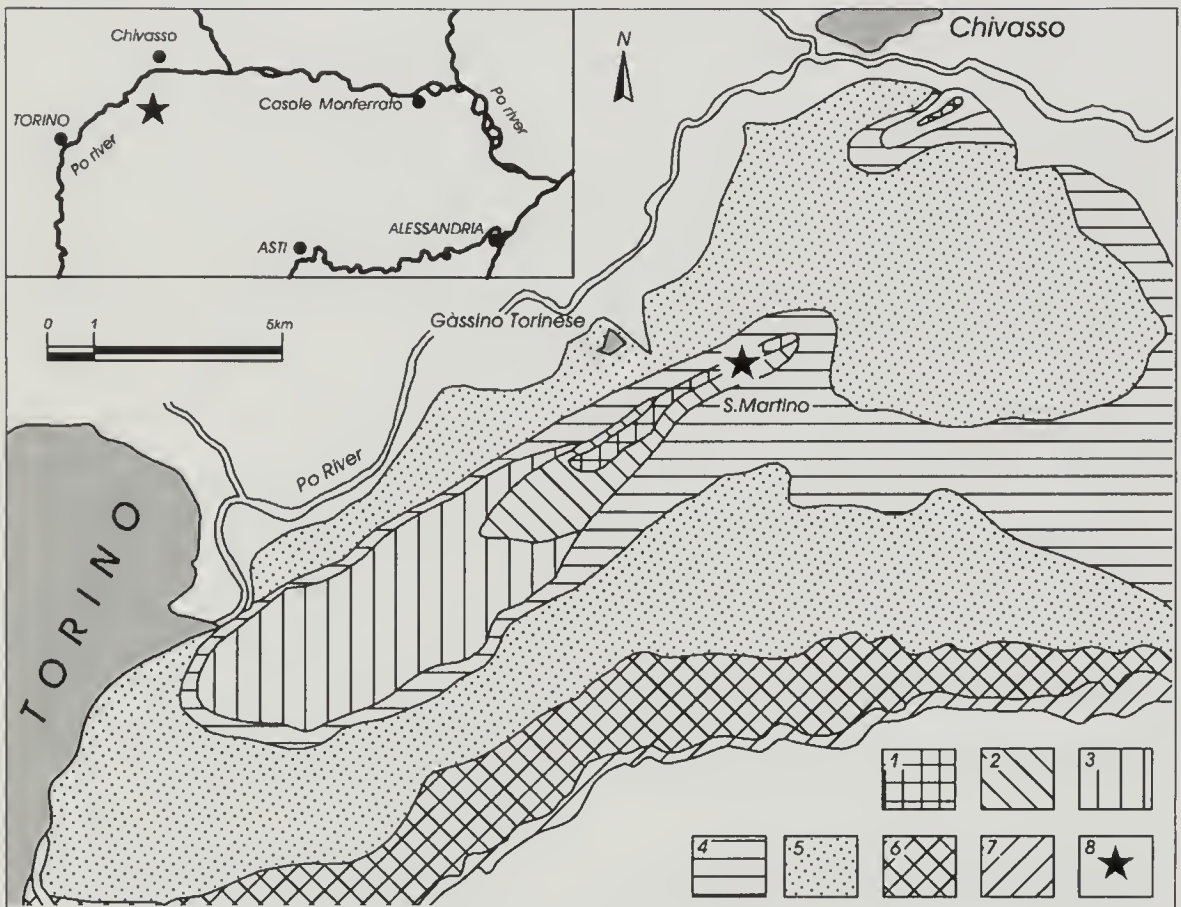


Fig. 1 - Geological sketch showing the areal distribution of the Gàsino Formation in the Torino Hill and the location of the San Martino outcrop. 1: Gàsino Fm. (Eocene), 2: Ranzano Fm. (Oligocene), 3: Superga Fm. (Aquitainian - Chattian), 4: Marne a Pteropodi Fm. (Middle Aquitainian - Upper Oligocene), 5: Baldissero Complex and Termo Forà Complex (Lower Tortonian - Upper Aquitainian), 6: grey shales (Tortonian), 7: shales with evaporitic lenses (Messinian), 8: location of San Martino outcrop (redrawn and slightly modified after Polino *et al.*, 1991).

Fig. 1 - Schema geologico che evidenzia la distribuzione areale della Formazione di Gàsino nella Collina di Torino e l'ubicazione dell'affioramento di San Martino. 1: Formazione di Gàsino (Eocene), 2: Formazione di Ranzano (Oligocene), 3: Formazione di Superga (Aquitainiano - Chattiano), 4: Marne a Pteropodi (Aquitainiano medio - Oligocene superiore), 5: Complesso di Baldissero e Complesso di Termo Forà (Tortoniano inferiore - Aquitainiano superiore), 6: peliti grigie (Tortoniano), 7: peliti con lenti di evaporiti (Messiniano), 8: ubicazione dell'affioramento di San Martino (da Polino *et al.*, 1991, ridisegnato e leggermente modificato).

structural domains of Torino Hill and Monferrato (Fig. 1). The former is the northern prosecution of the Langhe basin and is interpreted as an alpine-related domain, the latter is the NW termination of the northern Apennines (Polino *et al.*, 1991; Biella *et al.*, 1992, Miletto & Polino, 1992; Polino *et al.*, 1995). Torino Hill and Monferrato are separated by a convergent-wrench zone: the Rio Freddo Deformation Zone (for details see Miletto & Polino, 1992; Polino *et al.*, 1992; Clari *et al.*, 1994; Piana & Polino, 1994, 1995; Falletti *et al.*, 1995; Polino *et al.*, 1995).

The Gàssino Formation unconformably overlies the ligurian flysch (Cretaceous-Eocene) in the Monferrato domain and the alpine units in the Torino Hill, and underlies the Oligocene Ranzano Formation (Montrasio *et al.*, 1968; Gelati & Gnaccolini, 1988; Polino *et al.*, 1991; Falletti *et al.*, 1995).

The Gàssino Formation consists of grey-greenish or reddish marls and clays of open deep marine environment, redeposited sediments are rarely interbedded in the lower part of the formation (Montrasio *et al.*, 1968; Bonsignore *et al.*, 1969). These reworked bodies consist of bioclastic limestone and biocalcarenite showing a very rich fossil content that includes benthic foraminifera, molluscs, echinoderms, fish teeth, and red calcareous algae (Montrasio *et al.*, 1968; Bonsignore *et al.*, 1969). The fossils of these carbonate bodies have so far received little attention. Information on benthic foraminifers and red calcareous algae was provided by Di Rovasenda (1892), Trabucco (1908), Montrasio *et al.* (1968), and Consigliere *et al.* (2004).

Montrasio *et al.* (1968), Bonsignore *et al.* (1969), Gelati & Gnaccolini (1988), and Falletti *et al.* (1995) assign the Gàssino Formation to the Upper Eocene, while Clari *et al.* (1994) and Novaretti *et al.* (1995) to the Middle-Upper Eocene. Finally, the shallow benthic foraminifera assemblage reported from bioclastic limestone of Cascina Spinosa Alta (Gàssino Fm., Monferrato) points toward an uppermost middle Eocene age (Consigliere *et al.*, 2004).

The San Martino outcrop

In the neighbourhood of the San Martino locality the carbonate bodies of the Gàssino Formation are rare and occur as small lenses unevenly interbedded in the marly section. These bodies are made of packstone with rare siliciclastic fine grains. The abundant fossil content includes red calcareous algae, small solitary corals, bivalve and scaphopod shell fragments, echinoid plates and spines, bryozoans, globigerinids, gypsinids, miliolids, rare short alveolinids, acervulinids, rare chapmaninids, flattened medium-sized orthophragminids, and globose nummulitids. The latter two groups dominate the benthic foraminifera assemblage. Larger foraminifera are distorted, broken and very badly preserved, forms with globose morphology dominate the assemblage, flat ones are subordinate. The species *Asterocyclina stellata stellaris* (Rütimeyer, 1850), *Chapmanina gassinensis* (Silvestri, 1905) and *Acervulina linearis* (Hanzawa, 1947) have been recognised. According to Less (1998), Serra-Kiel *et al.* (1998) and Cahuzac & Poignant (1997), *Asterocyclina stellata stellaris* ranges from the boundary early/late Bartonian (SBZ 17/SBZ 18) to the early Priabonian (SBZ 19), and *Chapmanina*

gassinensis is distributed from the upper part of late Bartonian (SBZ 18) up to the lowermost part of the Oligocene (SBZ 21).

The age ranges of considered species indicate a time interval spanning from upper part of late Bartonian to the end of early Priabonian (i.e. uppermost SBZ 18 - SBZ 19).

Material and methods

Algae thalli come from hard rocks, from which it was impossible to obtain samples for a volumetric analysis. Therefore, a semiquantitative analysis has been performed, determining the percent frequency for subfamilies, genera and species. A total of 24 thin sections were studied. The abundance of each species has been evaluated by counting the thalli in every thin sections, the dominance is the proportion pertaining to each species in the assemblage (Tab. 1, 2). Algae occur as epigenous and unattached forms (*sensu* Woelkerling, 1988); among unattached, the free-living forms are abundant, but rare small rhodoliths are also present.

The growth morphology of thalli is described according to Woelkerling *et al.* (1993).

The taxonomic analysis at the ranks of family and subfamily has been carried out according to Harvey *et al.* (2003), and at the rank of genus, on the basis of the diagnostic characters accepted by the botanists (Womersley, 1996) and recently used by paleobotanists in descriptions and discussions of fossil calcareous red algae. As regards the species identification, it is noteworthy that the suggestion of some authors (e.g. Bassi & Nebelsick, 2000; Stockar, 2000) to use an open nomenclature, until the taxonomic review of type material has taken place, has not been followed. The specimens attributed to the genus *Lithothamnion* exhibit subepithallial cells that are longer than their immediate inward derivatives. All the reported species perfectly fit with morphologic and biometric features of the types.

The red calcareous algae assemblage

Among the very abundant epigenous forms (127 thalli), the encrusting morphology largely prevails (60), the warty one is subordinate but rather common, lumpy and foliose morphologies have been rarely recovered.

The abundant (72) free-living thalli are comparable to the branching density group I or, very rarely, to group II described by Bosence (1976, 1983a).

Six small, multispecific rhodoliths were recovered: five have elliptical shape and one spheroidal, the major dimension (axe or diameter) hardly exceeds 1.5 cm. Two rhodoliths exhibit laminar structure in the inner part and columnar in the outer, 4 are laminar.

The algae assemblage includes:

Sporolithon aschersonii (Schwager) Moussavian & Kuss, 1990

Sporolithon sp.1 Consigliere *et al.*, 2004

Sporolithon sp.2 Consigliere *et al.*, 2004

Lithoporella melobesioides (Foslie) Foslie, 1909

Lithoporella minus Johnson 1964

Neogoniolithon sp.1 Consigliere *et al.*, 2004
Neogoniolithon sp.2 Consigliere *et al.*, 2004
Jania nummulitica Lemoine, 1927
Jania mengaudii Lemoine, 1934
Lithothamnion valens Foslie, 1909
Lithothamnion cymbicrusta Johnson, 1957
Lithothamnion marianae Johnson, 1957
Lithothamnion pianfolchi Mastrorilli, 1968
Lithothamnion sp. Consigliere *et al.*, 2004
Mesophyllum fructiferum Airoidi, 1932
Polystrata alba (Pfender) Denizot, 1968

The following short comments on the structure of the algae assemblage are based on the semiquantitative analysis (Tabs. 1, 2).

Tab. 1 - Abundance of non-geniculate Corallinales and Peyssonneliaceae.

Tab. 1 - Abbondanza delle Corallinales non-genicolate e delle Peyssonneliaceae.

Species	Number of thalli unattached forms		epigenous forms	Total abundance
	in rhodoliths	free-living		
<i>Sporolithon aschersonii</i>	3	21	25	49
<i>Sporolithon</i> sp. 1	3	5	5	13
<i>Sporolithon</i> sp. 2	1	4	1	6
<i>Lithoporella melobesioides</i>	4		14	18
<i>Lithoporella minus</i>			3	3
<i>Neogoniolithon</i> sp. 1			10	10
<i>Neogoniolithon</i> sp. 2			21	21
<i>Lithothamnion cymbicrusta</i>			5	5
<i>Lithothamnion marianae</i>		1	5	6
<i>Lithothamnion pianfolchi</i>		6	7	13
<i>Lithothamnion valens</i>	2	25	9	36
<i>Lithothamnion</i> sp.		10	4	14
<i>Mesophyllum fructiferum</i>			10	10
<i>Polystrata alba</i>	5		8	13

Tab. 2 - Dominance of non-geniculate Corallinales and Peyssonneliaceae.

Tab. 2 - Dominanza delle Corallinales non-genicolate e delle Peyssonneliaceae.

Family & Subfamily		%	Genus	%	Species	%
Sporolitaceae		31.3	<i>Sporolithon</i>	31.3	<i>Sporolithon aschersonii</i>	22.5
					<i>Sporolithon</i> sp.	16.0
					<i>Sporolithon</i> sp.	22.8
Corallinaceae	Subfamily Mastophoroideae	24.0	<i>Lithoporella</i>	9.7	<i>Lithoporella melobesioides</i>	8.3
					<i>Lithoporella minus</i>	1.4
			<i>Neogoniolithon</i>	14.3	<i>Neogoniolithon</i> sp. 1	4.5
					<i>Neogoniolithon</i> sp. 2	9.8
Hapalidiaceae	Subfamily Melobesioideae	38.7	<i>Lithothamnion</i>	34.1	<i>Lithothamnion cymbicrusta</i>	2.3
					<i>Lithothamnion marianae</i>	2.8
					<i>Lithothamnion pianfolchi</i>	6.0
					<i>Lithothamnion valens</i>	16.5
					<i>Lithothamnion</i> sp.	6.5
			<i>Mesophyllum</i>	4.6	<i>Mesophyllum fructiferum</i>	4.6
Peyssonneliaceae		6.0	<i>Polystrata</i>	6.0	<i>Polystrata alba</i>	6.0

Lithothamnium (34.1%) and *Sporolithon* (31.3%) dominate the assemblage. *Sporolithon aschersonii* (22.5%) is the most abundant species, which is represented by fruticose free-living thalli and warty or lumpy epigenous specimens; this species also occur as rhodolith builder. *Lithothamnion valens* (16.5%) is also abundant and occurs with fruticose free-living habit, rarely with lumpy epigenous thalli; it is also present as rhodolith builder. *Lithothamnion* sp. (6.5%, Fig. 2), *Lithothamnion pianfolchi* (6.0%), and *Sporolithon* sp.1 (6.0%, Fig. 3) are represented by fruticose free-living thalli and by lumpy epigenous forms; *L. pianfolchi* also occurs with warty thalli. *Sporolithon* sp. 1 is present in the coating sequence of rhodoliths, while *Lithothamnion* sp. and *L. pianfolchi* are absent in these structures. *Lithothamnion marianae* (2.8%, Fig. 4) occurs with warty epigenous thalli and very rarely with fruticose free-living habit, it is not recovered in rhodoliths. *Sporolithon* sp. 2 (2.8%) is present with fruticose free-living specimens and in the coating sequence of rhodoliths. *Lithothamnion cymbicrusta* (2.3%, Fig. 5) occurs with encrusting epigenous thalli and is absent in rhodoliths.

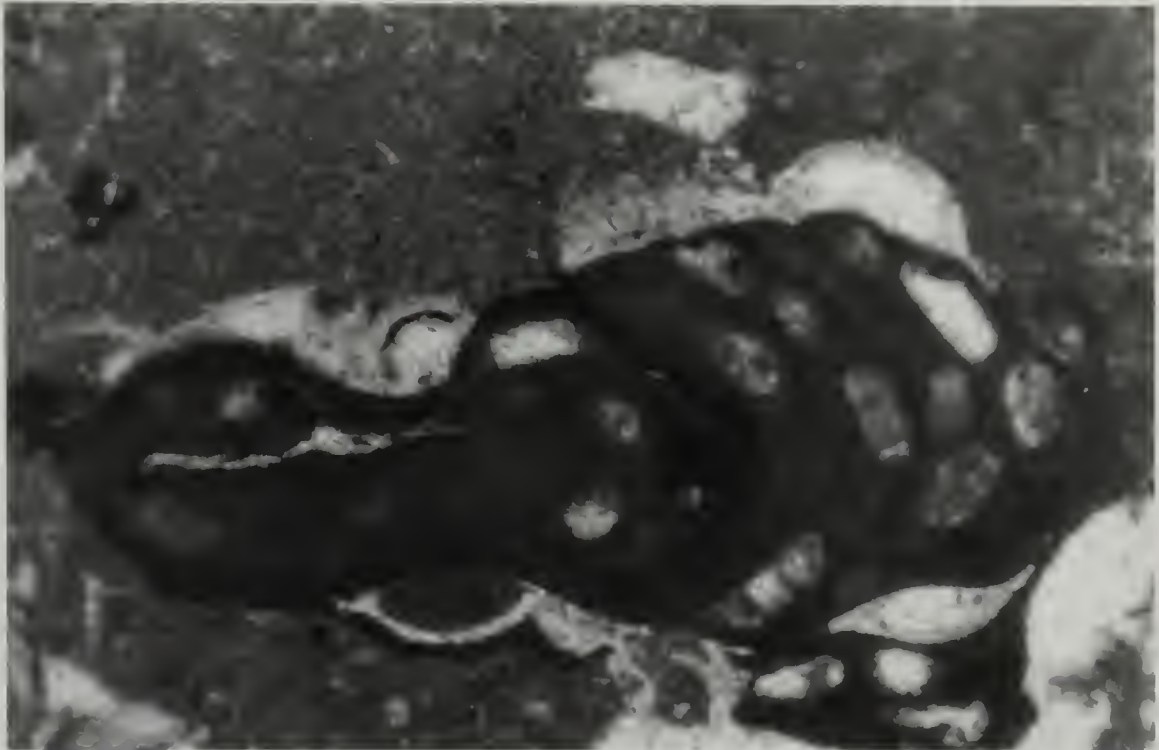


Fig. 2 - *Lithothamnion* sp. Consigliere *et al.*, 2004. Thin section SM-7, x52. Lumpy thallus with multiporate sporangial conceptacles.

Fig. 2 - *Lithothamnion* sp. Consigliere *et al.*, 2004. Sezione sottile SM-7, x52. Tallo intumescete con concettacoli sporangiali poliporici.

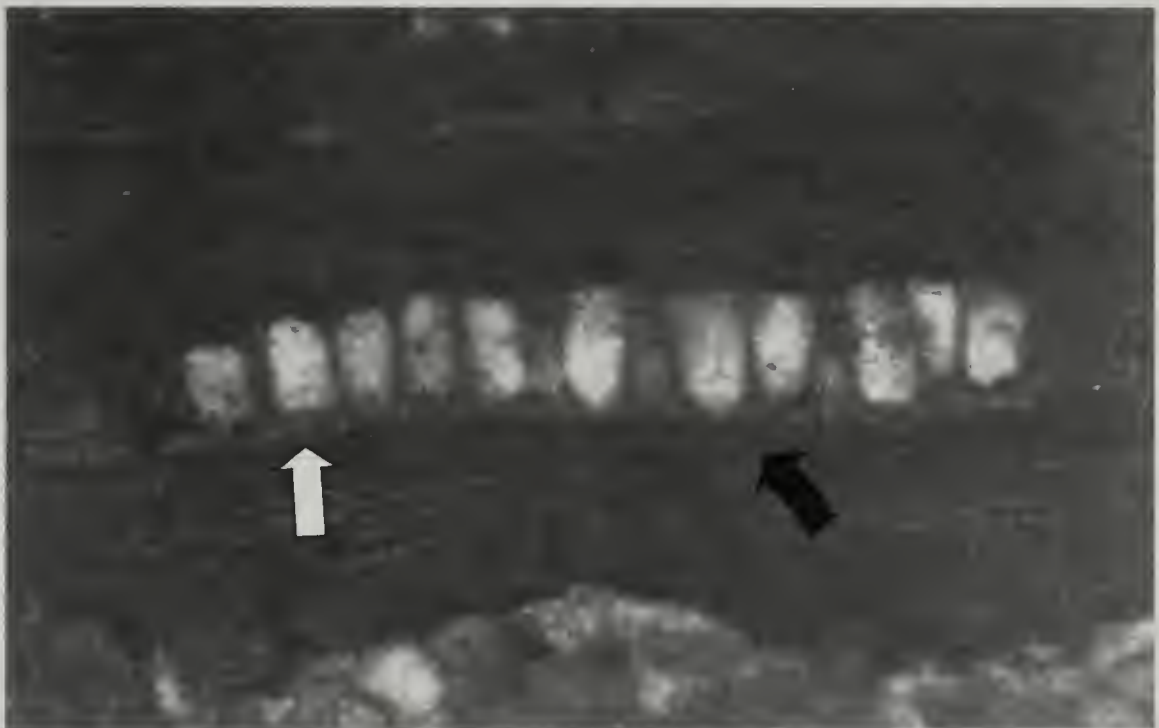


Fig. 3 - *Sporolithon* sp.1 Consigliere *et al.*, 2004. Thin section SM-3-IIIb, x130. Detail of a thallus with a basal layer of elongated cells at the base of sporangia (black arrow) and calcified septum at the base of several sporangial compartments (white arrow).

Fig. 3 - *Sporolithon* sp.1 Consigliere *et al.*, 2004. Sezione sottile SM-3-IIIb, x130.

Particolare di tallo che mostra alla base degli sporangi lo strato basale di cellule allungate (freccia nera) e localmente la presenza di un setto calcificato alla base della cavità sporangiale (freccia bianca).

Neogoniolithon (14.3%) and *Lithoporella* (9.7%) are significant members of the assemblage. *Neogoniolithon* sp. 1 (4.5%) and *Neogoniolithon* sp. 2 (9.8%, Fig. 6) occur respectively with encrusting and encrusting or foliose epigenous thalli; both species are lacking in rhodoliths. *Lithoporella melobesioides* (8.3%) and *Lithoporella minus* (1.4%) are represented by encrusting epigenous thalli; *L. melobesioides* is present in the rhodoliths, while *L. minus* is lacking.

Polystrata (6.0%) and *Mesophyllum* (4.6%) are less important. *Polystrata alba* (6.0%, Fig. 7) and *Mesophyllum fructiferum* (4.6%) occur with encrusting epigenous, only the former species is present in the coating sequence of rhodoliths.

The algae assemblage also includes geniculate coralline algae, which are represented by *Jania nummulitica* (15 intergenicula) and *Jania mengaudii* (4 intergenicula). Regarding the taxonomic structure (Tab. 2), subfamily Melobesioideae (38.7%) prevails and is the most diverse (2 genera, 6 species), but Sporolitaceae (31.3%) is also a very important element, even if reaches a low diversity (3 species). Mastophoroideae (24.0%) are less important. Peyssonneliaceae reach a low abundance. Corallinoideae reach a very low abundance and can be disregarded.



Fig. 4 - *Lithothamnion marianae* Johnson, 1957. Thin section SM-15, x50. Lumpy-fruticose sporangial thallus.

Fig. 4 - *Lithothamnion marianae* Johnson, 1957. Sezione sottile SM-15, x50. Tallo sporangiale intumescente-ramoso.

Paleoecological remarks

Globose nummulitids dominate the foraminifera assemblage, flat orthophragminids are subordinate but reach a significant abundance, other groups (i.e.: planktonic and small benthic foraminifera, alveolinids, acervulinids and chapmaninids) are occasionals and occur with few and poorly preserved specimens.

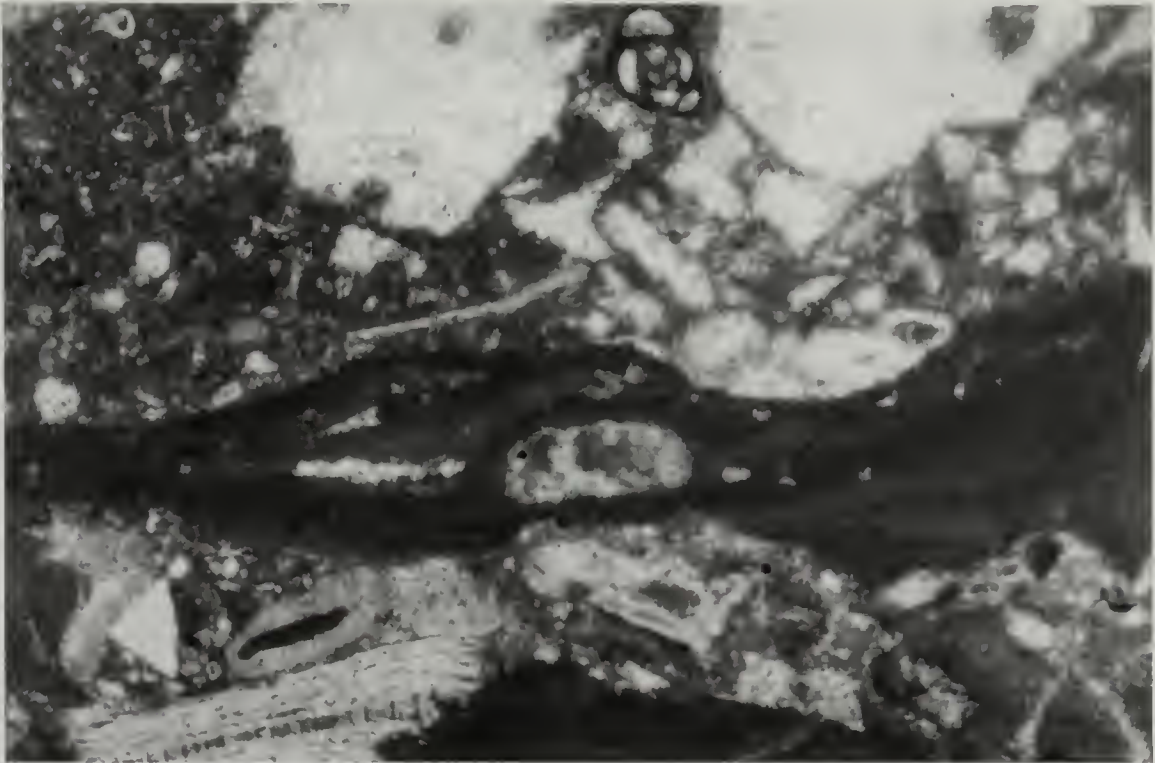


Fig. 5 - *Lithothamnion cymbicrusta* Johnson, 1957. Thin section SM-12, x52. Encrusting thallus with multiporate spore conceptacle.

Fig. 5 - *Lithothamnion cymbicrusta* Johnson, 1957. Sezione sottile SM-12, x52. Tallo crostoso con concettacolo sporangiale poliporico.



Fig. 6 - *Neogoniolithon* sp.2 Consigliere *et al.*, 2004. Thin section SM-14, x50. Foliose thallus.

Fig. 6 - *Neogoniolithon* sp.2 Consigliere *et al.*, 2004. Sezione sottile SM-14, x50. Tallo fogliaceo-laminare.

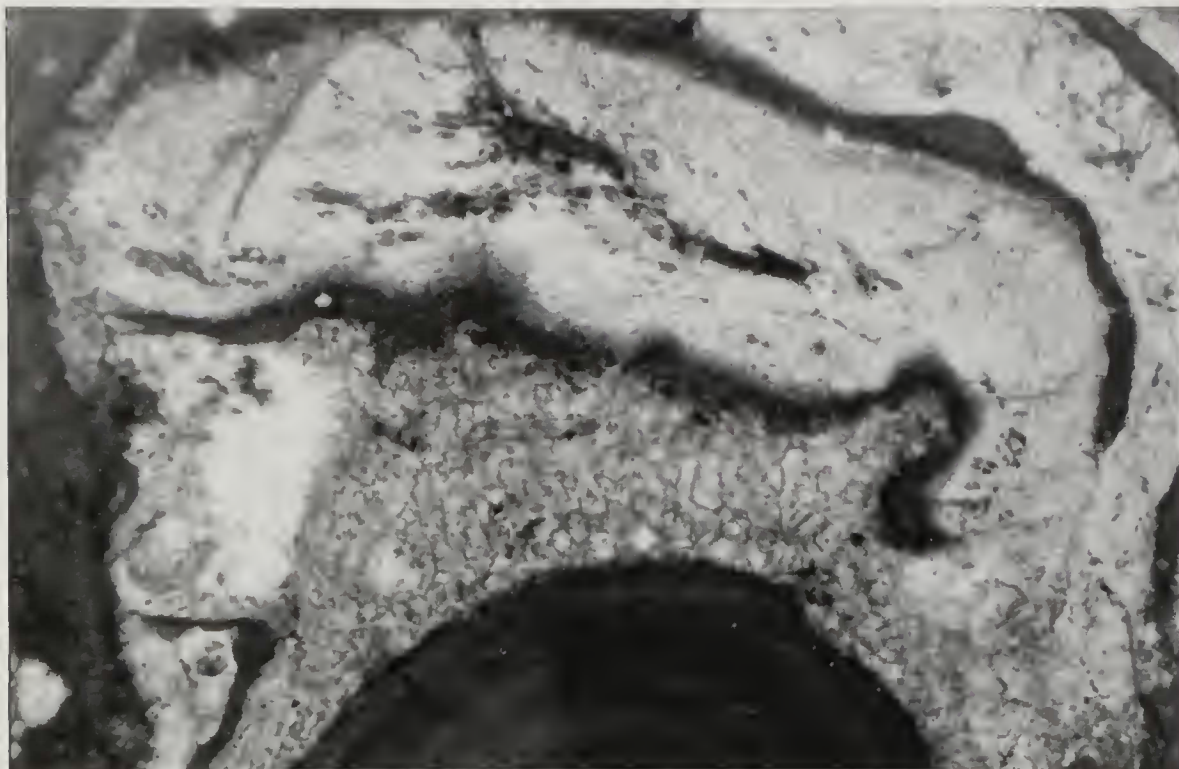


Fig. 7 - *Polystrata alba* (Pfender) Denizot, 1968. Thin section SM-11, x50. Foliose thalli forming the outer part of a rhodolith.

Fig. 7 - *Polystrata alba* (Pfender) Denizot, 1968. Sezione sottile SM-11, x50. Talli fogliaceo-laminari costituenti la parte esterna di una rodolite.

Orthophragminids and nummulitids are restricted to normal marine warm waters, requiring, respectively, a temperature above 25°C (Less, 1987) and higher than 20°C (Blondeau, 1972).

According to Hallock & Glenn (1986) and Boltovskoy *et al.* (1991) thicker and spheroidal larger foraminifera are commonly related to environments shallower than those inhabited by flat and thinner-tested forms and the occurrence of flat larger foraminifera and, among these, the presence of *Asterocyclina*, indicate a relatively deep environment with a low-energy hydrodynamic conditions.

Middle-upper Eocene *Asterocyclina* is reported to dwell on outer platform (Papazzoni, 1994) and deeper fore slope (Hallock & Glenn, 1986) and from the upper to the lower photic zone, i.e. 40-120 depth interval (Hottinger, 1997). The recovered globose nummulitids may be compared to the middle-upper Eocene thick *Nummulites*, that inhabited the shallower fore slope (Hallock & Glenn, 1986) and the 40-80 m deep upper photic zone environments (Hottinger, 1997).

Pignatti (1994) suggests that *C. gassinensis* lived in shallow water affected by high energy conditions. Papazzoni (1994) and Papazzoni & Sirotti (1995) listed this species as characteristic of low energy inner platform environment.

Living alveolinids are typically found in warm, shallow, metahaline waters of moderately high energy (Chaproniere, 1975). Fossil alveolinids are shallow-water forms probably restricted to sheltered locations (Ghose, 1977). Papazzoni (1994) includes the Eocene alveolinids in the list of foraminifera related to the low water

energy inner platform. According to Geel (2000: 214), Palaeogene alveolinids "... may live on all kinds of substrate in relatively shallow water (0-75 m water-depth). Prolific growth occurs in clear protected areas in the backreef and in interreefal sands near and below wave base.". Finally, Hottinger (1997) allocates the Eocene alveolinids in the upper photic zone (depth interval: ca. 0-80 m) and states that the short forms occur in the shallower part (i.e. 0-40 m ca.).

Referring to the models for the distribution of foraminifera in the depth gradient proposed by Hallock & Glenn (1986), Papazzoni (1994) and Hottinger (1997), the present foraminifera assemblage may be considered indicative of a 40-80 m deep warm outer platform environment (Circalittoral Zone). *C. gassinensis* and the undetermined short alveolinids have been probably re-worked from a shallower environment; their scarcity together with the poor state of preservation confirms this hypothesis.

The abundant presence of *Sporolithon* and *Lithoporella* suggests a tropical or subtropical climate (Lemoine, 1940, 1976; Adey & Macintyre, 1973; Wray, 1977; Bosence, 1983b; Piller, 2003). In these warm water conditions, the dominance of Melobesioideae and Sporolithaceae indicates a deep environment (Adey & Macintyre, 1973; Wray, 1977; Adey, 1979; Adey *et al.*, 1982; Minnery, 1990; Bosence, 1991; Marshall *et al.*, 1998; Aguirre *et al.*, 2000; Lund *et al.*, 2000; Braga & Aguirre, 2001) and might be indicative of a Circalittoral allocation, within a depth range of 60-100 m, possibly down to 200 m (according to the Miocene - Recent bathymetric zonation proposed by Bosence, 1991); but the significant proportion of Mastophoroideae restricts the inferred bathymetric interval to the mid-upper part of the Circalittoral Zone, i.e. 60-100 m ca. (according to the suggestion of Aguirre *et al.*, 2000).

Adey *et al.* (1982: 35) report that the extant species *Lithoporella melobesioides* is distributed from intertidal to 85 m in Hawaiian Islands, but the authors suggest that "Considering the wide depth range ... it is possible that we mixed several species". A strong abundance of living unattached branched thalli of *Litothamnion valens* defines a facies of the Coastal Detritic Bottom (DC) of the soft substrates of Circalittoral Zone of Mediterranean Sea (Pérès & Picard, 1964; Pérès, 1982; Basso *et al.*, 1998).

Corallinoideae are distributed from tropical to temperate waters and are most frequent at shallow depths in high energy conditions (Ghose, 1977; Wray, 1977), but the few fragmented specimens here recovered is not considered, because the disarticulated intergenicula can be easily transported.

The dominance of encrusting and foliose morphologies and of free-living thalli of branching density group I indicates low energy conditions (according to Bosence, 1983a; 1991). The structures of the rhodoliths (four of the six recovered rhodoliths exhibit a laminar structure and two laminar in the inner part, grading to columnar in the outer) suggest moderate energy conditions (according to Bosellini & Ginsburg, 1971, and Bosence, 1983a, 1983b, 1991). From these two lines of evidence, a moderate-low hydrodynamic regime can be inferred.

As a whole, this algae assemblage can be considered typical of tropical/subtropical, mid-upper circalittoral bottoms (depth range: 60-100 m) under the influence of moderate-low hydrodynamic regime. As above recorded, the Mastophoroids significant

proportion is consistent with the proposed bathymetric allocation, therefore the few Corallinoideae are the unique allochthonous element of the algae assemblage. To conclude, the recovered benthic foraminifera and red calcareous algae assemblages are probably re-worked from tropical/subtropical, 60-80 m deep circalittoral bottoms, affected by moderate energy conditions.

Paleobiogeographic remarks

The following comments on species biogeography are based on reliable information from literature and focused on Eocene distribution. The detailed paleogeographic distribution of considered species has been recently recorded by Consigliere *et al.* (2004).

Larger foraminifera and red calcareous algae species are grouped on the basis of their paleogeographic affinity, i.e.: Indo-Pacific & Tethyan-Paleomediterranean species, Tethyan-Paleomediterranean species. Corallinoideae are not considered.

Indo-Pacific & Tethyan-Paleomediterranean species: *Asterocyclina stellata stellaris*, *Chapmanina gassinensis*, *Lithothamnion cymbicrusta*, *Lithothamnion marianae*, *Sporolithon aschersonii*, *Lithoporella minus*, *Lithoporella melobesioides*, *Polystrata alba*.

Tethyan-Paleomediterranean species: *Lithothamnion pianfolchi*, *Lithothamnion valens*, *Mesophyllum fructiferum*.

In summary, the bulk of considered species are Tethyan-Paleomediterranean, some of which, during the Eocene, extend their range to the Indo-Pacific area.

Conclusions and comparisons

The reworked bioclastic limestone bodies of San Martino may be assigned to the time interval spanning from the upper part of late Bartonian to the end of early Priabonian (i.e. uppermost SBZ 18 - SBZ 19), on the basis of the recovered shallow benthic foraminifera assemblage.

The benthic foraminifera and red calcareous algae assemblages indicate a provenance from tropical/subtropical circalittoral bottoms about 60-80 m deep, influenced by moderate energy conditions.

The bulk of considered algae and foraminifera are Tethyan-Paleomediterranean species, and some of these forms, during the Eocene, are also present in the Indo-Pacific area.

The San Martino larger foraminifera and red calcareous algae assemblages are rather similar to those described by Stockar (1997, 1999) from the clasts of the Eocene Ternate Formation occurring in the Quaternary deposits of Prella (Canton Ticino, Switzerland).

As regards the Bartonian - early Rupelian larger foraminifera and Corallinales assemblages recovered from the Ternate Formation (Northern Italy) by Mancin *et al.* (2001), any comparison is difficult because of the lack of quantitative/semi-quantitative data. But, it is of note that the Ternate algae assemblage differs by the presence of *Spongites* and the absence of *Neogoniolithon*.

The San Martino (here afterwards abbreviated to SM) bioclastic limestones might be of younger age (i.e.: upper part of late Bartonian - early Priabonian, uppermost SBZ 18 - SBZ 19), than those recovered at Cascina Spinosa Alta (here afterwards abbreviated to CSA), that were assigned to upper part of late Bartonian (SBZ 18). But a note of caution is made here because of the rarity and bad preservation of the age-diagnostic forms in SM rocks.

The SM larger foraminifera assemblage differs from those of CSA being dominated by globose nummulitids with subordinate flat orthophragminids, but the comparison is difficult because of the very bad preservation of SM forms.

The SM algae assemblage is very similar to CSA assemblage, the difference are: a) the higher number of mastophoroid species occurring in CSA material (i.e.: Mastophoroideae sp. 1, Mastophoroideae sp. 2, *Spongites* sp.), b) the higher proportion of Mastophoroideae in SM assemblage (SM= 24.0%, CSA= 14.2%), c) the higher proportion of *Polystrata alba* in SM assemblage (SM= 6.0%, CSA= 3.2%), d) the lower proportion of taxa indicative of deeper environment in warm water (i.e.: Sporolithaceae and Melobesioideae) in SM (Sporolithaceae + Melobesioideae in SM = 70%, in CSA = 82.6%).

As regards the paleoecological meaning of the SM and CSA assemblages, it is noteworthy that: 1) both SM and CSA algae and foraminifera assemblages indicate a tropical/subtropical normal marine warm water environment; 2) the SM ones indicate a bathymetric allocation slightly shallower (i.e. upper photic zone, ca. 40-80 m) than those of CSA, that were regarded to be indicative of bottoms located at the upper and lower photic zone border (ca. 80 m); 3) both SM and CSA assemblages suggest moderate energy conditions, but, probably, the SM paleoenvironment was affected by a slightly higher hydrodynamic regime, because of the dominance of globose nummulitids, the higher proportion of Mastophoroideae, and the higher occurrence of laminar rhodoliths.

The above reported differences suggest that the SM and CSA materials were reworked in different time from contiguous areas. If so, the bioclastic sediments were progressively removed from the deeper to the shallower part of the outer platform, during a time interval spanning from the upper late Bartonian to the early Priabonian. This fact might represent an evidence of a space and time-transgressive instability condition due to tectonic or climatic events.

Acknowledgements

This paper has greatly profited of critical reading by two anonymous reviewers. G. Salvemini and G. M. Dabove made the electronic version of drawings. Work supported by research funds Ricerca di Ateneo, Università degli Studi di Genova.

References

- Adey W. H., 1979 - Crustose Coralline Algae as microenvironmental indicators for the Tertiary. In: Historical Biogeography, Plate Tectonics and the Changing Environment. Gray J. & Boucot A.J. (eds.). *Oregon State Univ. Press*, Corvallis: 459-464.

- Adey W. H. & Macyntire I.G., 1973 - Crustose Coralline Algae: A re-evaluation in the Geological Sciences. *Geol. Soc. Am. Bull.*, Boulder, 84 (3): 883-904.
- Adey W. H., Townsend R.A. & Boykins W.T., 1982 - The Crustose coralline Algae (Rhodophyta, Corallinaceae) of the Hawaiian Islands. *Smith. Contr. Marine Sci.*, Washington, 15: 1-74.
- Aguirre J., Riding R. & Braga J.C., 2000 - Diversity of Coralline Red Algae: origination and extinction patterns from the early Cretaceous to the Pleistocene. *Paleobiology*, Lancaster, 26 (4): 651-667.
- Airoldi M., 1932 - Contributo allo studio delle corallinacee del terziario italiano. Le Corallinacee dell'Oligocene ligure-piemontese. *Paleont. Ital., Mem. Paleont.*, Siena, 33: 55-83.
- Bassi D. & Nebelsick J.H., 2000 - Calcareous algae from the Lower Oligocene Gornji Grad beds of Northern Slovenia. *Riv. Ital. Paleont. Strat.*, Milano, 106 (1): 99-122.
- Basso D., Fravega P., Piazza M. & Vannucci G., 1998 - Biostratigraphic, paleobiogeographic and paleoecological implications in the taxonomic review of Corallinaceae. *Rend. Fis. Acc. Lincei*, Roma, 9 (9): 201-211.
- Biella G., Clari P., De Franco R., Gelati R., Ghibaud G., Gnaccolini M., Lanza R., Polino R., Ricci B. & Rossi B., 1992 - Geometrie cristalline al nodo Alpi/Appennino: conseguenze sull'evoluzione cinematica dei bacini neogenici. *Riass. 76° Congr. Soc. Geol. It.*, Roma: 192-195.
- Blondeau A., 1972 - Les Nummulites. *Vuibert*, Paris.
- Boltovskoy E., Scott D.B. & Medioli F.S., 1991 - Morphological Variations of Benthic Foraminiferal Test in Response to Changes in Ecological Parameters: A Review. *Journ. Paleont.*, Tulsa, 65 (2): 175-185.
- Bonsignore G., Bortolami G., Elter G., Montrasio A., Petrucci F., Ragni U., Sacchi R., Sturani C. & Zanella E., 1969 - Note Illustrative della Carta Geologica d'Italia, Fogli 56 e 57 Torino - Vercelli. *Poligrafica & Cartevalori*, Ercolano.
- Bosellini A. & Ginsburg R.N., 1971 - Form and internal structure of recent algal nodules (Rhodolithes) from Bermuda. *Journ. Geol.*, Chicago, 79: 669-682.
- Bosence D. W. J., 1976 - Ecological studies on two carbonate sediment producing coralline algae from western Ireland. *Palaeontology*, London, 19: 365-395.
- Bosence D. W. J., 1983a - Description and classification of Rhodoliths (Rhodoids, Rhodolithes). In: Coated Grains. Peryt T.M. (ed.). *Springer-Verlag*, Berlin: 217-224.
- Bosence D. W. J., 1983b - The occurrence and ecology of recent Rhodoliths - A review. In: Coated Grains. Peryt T.M. (ed.). *Springer-Verlag*, Berlin: 225-243.
- Bosence D. W. J., 1991 - Coralline Algae: Mineralization Taxonomy and Palaeoecology. In: Calcareous Algae and Stromatolites. Riding R. (ed.). *Springer-Verlag*, Berlin: 98-113.
- Braga J. C. & Aguirre J., 2001 - Coralline algal assemblages in upper neogene reef and temperate carbonates in Southern Spain. *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, Amsterdam, 175: 24-41.
- Cahuzac B. & Poignant A., 1997 - Essai de biozonation dans les bassins européens a l'aide des grands foraminifères néritiques. *Bull. Soc. géol. France*, Paris, 168 (2): 155-169.

- Chaproniere G. C. H., 1975 - Palaeoecology of Oligo-miocene larger Foraminiferida, Australia. *Alcheringa*, Canberra, 1: 37-58.
- Clari P., Dela Pierre F., Novaretti A. & Timpanelli M., 1994 - La successione oligo-miocenica del Monferrato occidentale: confronti e relazioni con il Monferrato orientale e la Collina di Torino. *Atti Tic. Sc. Terra*, Pavia, Ser. Spec. 1: 191-203.
- Consigliere C., Fravega P., Piazza M., Stockar R. & Vannucci G., 2004 - Larger foraminifera and red calcareous algae from Gàssino Formation: the Cascina Spinosa Alta assemblages (Eocene, Monferrato, NW Italy). *Atti Ticin. Sci. Terra*, Pavia, 45: 11-22.
- Denizot M., 1968 - Les algues Floridées encrustantes (à l'exclusion des Corallinacées). *Mus. Nat. Hist. Nat.*, Paris.
- Di Rovasenda L., 1892 - I fossili di Gàssino. *Boll. Soc. Geol. Ital.*, Roma, 11: 409-424.
- Falletti P., Gelati R. & Rogledi S., 1995 - Oligo-Miocene evolution of Monferrato and Langhe, related to deep structures. In: *Atti del Convegno Rapporti Alpi-Appennino e Guida alle Escursioni*. Polino R. & Sacchi R. (eds.). *Acc. Naz. Sci., Scritti e Documenti*, Roma, XIV: 1-20.
- Foslie M., 1909 - Algologiske notiser VI. *Det. Kgl. Norske Vid. Sels. Skr.*, Trondhjem, 2: 1-63.
- Geel T., 2000 - Recognition of stratigraphic sequences in carbonate platform and slope deposits: empirical models based on microfacies analysis of Palaeogene deposits in southern Spain. *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, Amsterdam, 155: 211-238.
- Gelati R. & Gnaccolini M., 1988 - Sequenze deposizionali in un bacino episuturale, nella zona di raccordo tra Alpi ed Appennino Settentrionale. *Atti Ticin. Sc. Terra*, Pavia, 31: 340-350.
- Ghose B. K., 1977 - Paleoecology of the Cenozoic reefal Foraminifers and algae - a brief review. *Palaeogeogr. Palaeoclim. Palaeoecol.*, Amsterdam, 22: 231-256.
- Hallock P. & Glenn E.C., 1986 - Larger Foraminifera: A Tool for Paleoenvironmental Analysis of Cenozoic Carbonate Depositional Facies. *Palaios*, Los Angeles, 1 (1): 55-64.
- Hanzawa S., 1947 - Reinstatement of the genus *Heterosteginoides*, and the classification of the Miogypsinidae. *Jour. Paleontol.*, Tulsa, 21 (3): 260-263.
- Harvey A. S., Broadwater S.T., Woelkerling W.J. & Mitrovski P.J., 2003 - *Choreonema* (Corallinales, Rhodophyta): 18S rDNA phylogeny and resurrection of the Hapalidiaceae for the Subfamilies Choreonematoideae, Austrolithoideae, and Melobesioideae. *Journ. Phycology*, Oxford, 39 (5): 988-998.
- Hottinger L., 1997 - Shallow benthic foraminiferal assemblages as signals for depth of their deposition and their limitations. *Bull. Soc. géol. France*, Paris, 168 (4): 491-505.
- Johnson J. H., 1957 - Geology of Saipan, Mariana Islands. Calcareous Algae. *U.S. Geol. Surv. Prof. Paper*, Washington, 280E: 209-243.
- Johnson J. H., 1964 - Eocene Algae from Ishigaki Shima, Ryukyu-Retto. *U.S. Geol. Surv. Prof. Paper*, Washington, 399C: 1-13.
- Lemoine M. (Mme P.), 1927 - Sur quelques Algues calcaires du Nummulitique de la Haute-Savoie. *Bull. Mus. Natl. Hist. Nat.*, Paris, 33: 545-551.

- Lemoine M. (Mme P.), 1934 - Algues calcaires de la famille des Corallinacées recueillies dans les Carpathes occidentales par M. D. Andrusov. *Vest. Ser. Géol. Rép. Tchécoslovaque*, Praha, IX (5): 269-189.
- Lemoine M. (Mme P.), 1940 - Les Algues calcaires de la zone neritique. *Soc. Biogéogr.*, Paris, 7: 75-138.
- Lemoine M. (Mme P.), 1976 - Le genre *Lithoporella* Foslie (algue Rhodophycée Corallinacée) au Tertiaire et au Quaternaire. *Bull. Soc. géol. France*, Paris, 7 (18): 773-787.
- Less G., 1987 - Paleontology and stratigraphy of the European Orthophragminae. *Geol. Hungar.*, (Palaeontol.), Budapest, 51: 1-373.
- Less G., 1998 - The zonation of the mediterranean Upper Paleocene and Eocene by Orthophragminae. *Dela-Opera SAZU 4. Razr.*, Ljubljana, 34 (2): 21-43.
- Lund M., Davies P.J. & Braga J.C., 2000 - Coralline algal nodules off Fraser Island, Eastern Australia. *Facies*, Erlangen, 42: 25-34.
- Mancin N., Ceriani A., Tagni F. & Brambilla G., 2001 - La Formazione di Ternate (Italia settentrionale): contenuto micropaleontologico e caratterizzazione petrografica. *Atti Ticin. Sc. Terra*, Pavia, 42: 37-46.
- Marshall J. F., Tsuji Y., Mutsuda H., Davies P.J., Iryus Y., Honda N. & Satoh Y., 1998 - Quaternary and Tertiary subtropical carbonate platform development on the continental margin of southern Queensland, Australia. *Spec. Publ. Int. Ass. Sediment.*, Oxford, 25: 163-195.
- Mastorilli V. I., 1968 - Nuovo contributo allo studio delle Corallinacee dell'Oligocene Ligure-Piemontese: i reperti della tavoletta Ponzone. *Atti Ist. Geol. Univ. Genova*, Genova, 5 (2): 153-406.
- Miletto M. & Polino R., 1992 - A gravity model of the crust beneath the Tertiary Piemonte basin (Northwestern Italy). *Tectonophysics*, Amsterdam, 212: 243-456.
- Minnery G. A., 1990 - Crustose coralline algae from the Flower Garden Banks, northwestern Gulf of Mexico: controls on distribution and growth morphology. *Journ. Sedim. Petrol.*, Tulsa, 60 (6): 992-1007.
- Montrasio A., Premoli Silva I. & Ragni U., 1968 - Osservazioni geologico-stratigrafiche sulla regione compresa tra Casale Monferrato, Vignale, Alfiano Natta e Gabiano. *Boll. Soc. Geol. It.*, Roma, 87: 581-609.
- Moussavian E. & Kuss J., 1990 - Typification and status of *Lithothamnium aschersoni* Schwager, 1883 (Corallinaceae, Rhodophyta) from Paleocene Limestone of Egypt. A contribution to the synonymy and priority of the genera *Archaeolithothamnium* Rothpletz and *Sporolithon* Heydrich. *Berliner geowiss. Abh. (A)*, Berlin, 120 (2): 929-942.
- Novaretti A., Bicchi E., Condello A., Ferrero E., Maia F., Tonon M. & Torta D., 1995 - La successione oligo-miocenica del Monferrato: sintesi dei dati biostratigrafici. In: Atti del Convegno Rapporti Alpi-Appennino e Guida alle Escursioni. Polino R. & Sacchi R. (eds.). *Acc. Naz. Sci., Scritti e Documenti*, Roma, XIV: 39-59.
- Papazzoni C. A., 1994 - Macroforaminifera and paleoenvironments near the Middle-Upper Eocene boundary in the Mossano section (Berici Mts., Vicenza, northern Italy). In: Studies on Ecology and Paleoecology of Benthic Communities. Matteucci R., Carboni M.G. & Pignatti J.S. (eds.). *Boll. Soc. Paleont. Ital.*, Modena, Spec. Vol. 2: 203-212.

- Papazzoni C. A. & Sirotti A., 1995 - Nummulite biostratigraphy at the Middle/Upper Eocene boundary in the northern Mediterranean area. *Riv. Ital. Paleont. Strat.*, Milano, 101 (1): 68-80.
- Pérès J. M., 1982 - Structure and dynamics of assemblages in the benthic. In: Marine Ecology. Kinne O. (ed.). *John Wiley & Sons Ltd*, New York, 5 (1): 119-581.
- Pérès J. M. & Picard J., 1964 - Nouveau manuel de bionomie benthique de la Mer Méditerranée. *Rec. Trav. St. Mar. Endoume Bull.*, Endoume, 31: 1-137.
- Piana F. & Polino R., 1994 - La zona transpressiva di Rio Freddo e l'evoluzione convergente della Collina di Torino e del Monferrato durante il Terziario. *Atti Ticin. Sc. Terra*, Pavia, ser. spec. 1: 167-180.
- Piana F. & Polino R., 1995 - Tertiary structural relationships between Alps and Apennines: the critical Torino Hill and Monferrato area, Northwestern Italy. *Terra Nova*, Oxford, 7: 138-143.
- Pignatti J. S., 1994 - Biostratigrafia dei macroforaminiferi del Paleogene della Maiella nel quadro delle piattaforme periadriatiche. *Studi Geol. Camerti*, Camerino, vol. spec. 1994: 359-405.
- Piller W. E., 2003 - Miocene carbonates in the western central Paratethys - an unexpected development. In: Abstracts, Workshop: Oligo-Miocene shallow water carbonates: biogenic components and facies. Bassi D. (ed.). *Ann. Univ. Ferrara, NS, sez. Sci. Terra*, Ferrara, 10 (suppl.): 13-14.
- Polino R., Clari P., Crispini L., d'Atri A., Dela Pierre F., Novaretti A., Piana F., Ruffini R. & Timpanelli M., 1995 - Relazioni tra zone di taglio crostali e bacini sedimentari: l'esempio della giunzione alpino-appenninica durante il terziario. Guida all'escursione in Monferrato e nella Zona Sestri-Voltaggio. In: Atti del Convegno Rapporti Alpi-Appennino e Guida alle Escursioni. Polino R. & Sacchi R. (eds.). *Acc. Naz. Sci., Scritti e Documenti*, Roma, XIV: 531-593.
- Polino R., Gelati R., Rossi P.M., Biella G. & De Franco R., 1992 - Crustal structures beneath the southern Piemonte (North-Western Italy): consequences on kinematic of the Alps/Appennines boundary. *Géol. Alpine*, Grenoble, Sér. Spéc. Colloques et excursions 1: 74-75.
- Polino R., Ruffini R. & Ricci B., 1991 - Le molasse terziarie della Collina di Torino: relazioni con la cinematica alpina. *Atti Ticin. Sc. Terra*, Pavia, 34: 85-89.
- Rüttimeyer L., 1850 - Über das schweizerische Nummulitenterrain mit besonderer Berücksichtigung des Gebirges zwischen den Thunersee und der Emme. *N. Denkschr. schweiz. natf. Ges.*, Zürich, 11: 1-120.
- Serra-Kiel J., Hottinger L., Caus E., Drobne K., Ferrandez C., Jauhri A.K., Less G., Pavlovec R., Pignatti J., Samso J.M., Schaub H., Sirel E., Strougo A., Tambareau Y., Tosquella J. & Zakrevskaya E., 1998 - Larger Foraminiferal Biostratigraphy of the Tethyan Paleocene and Eocene. *Bull. Soc. géol. France*, Paris, 169 (2): 281-299.
- Silvestri A., 1905 - La *Chapmania gassinensis* Silv. *Riv. Ital. Paleontol.*, Milano, XI (3): 113-120.
- Stockar R., 1997 - Contributo alla conoscenza dell'Eocene nel Canton Ticino: l'associazione ad Alghe Calcareae fossili di Prella (Mendrisiotto). *Boll. Soc. ticin. Sci. nat.*, Lugano, 85: 23-46.

- Stockar R., 1999 - I macroforaminiferi eocenici negli inclusi dei depositi quaternari della collina di Prella (Ticino meridionale, Svizzera). *Geol. Insubr.*, Morbio Inferiore, 4 (2): 1-20.
- Stockar R., 2000 - Fossil coralline algae from the Paleocene Montorfano Member type-section (Tabiago Formation, northern Italy). *Eclogae geol. Helv.*, Basel, 93 (3): 409-427.
- Trabucco G., 1908 - Fossili, stratigrafia ed età del Calcarea di Acqui (Alto Monferrato). *Boll. Soc. Geol. It.*, Roma, 27: 337-400.
- Woelkerling Wm. J., 1988 - The Coralline Red Algae: An Analysis of the Genera and Subfamilies of Nongeniculate Corallinaceae. *Oxford Univ. Press*, Oxford.
- Woelkerling Wm. J., Irvine L.M. & Harvey A.S., 1993 - Growth forms in Nongeniculate Coralline Red Algae (Corallinales, Rhodophyta). *Aust. Syst. Bot.*, Melbourne, 6: 277-293.
- Womersley H. B. S., 1996 - The marine benthic flora of Southern Australia. Rhodophyta - Part IIIB. *Australian Biological Resources Study*, Canberra.
- Wray J.L., 1977 - Calcareous Algae. *Elsevier Scient. Publ. Co.*, Amsterdam.

Ricevuto: dicembre 2005

Approvato: gennaio 2006